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Prior Coronary Artery Bypass Graft Patients With ST-Segment Elevation Myocardial Infarction Treated With Primary Percutaneous Coronary Intervention

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Objectives We sought to compare outcomes in ST-segment elevation myocardial infarction (STEMI) patients undergoing primary percutaneous coronary intervention (PCI) with or without previous coronary artery bypass grafts (CABG).

Background Limited information exists regarding procedural success and clinical outcomes of STEMI patients with CABG undergoing primary PCI.

Methods The APEX-AMI (Assessment of Pexelizumab in Acute Myocardial Infarction) trial was a randomized, placebo-controlled trial of pexelizumab in STEMI patients with planned primary PCI: 128 of 5,745 (2.2%) patients had prior CABG. Clinical/procedural characteristics, culprit vessel (infarct-related artery [IRA]), and 90-day clinical outcomes were compared.

Results Patients with previous CABG were more frequently men, older, had a higher incidence of comorbidities and multivessel disease. In patients with versus without prior CABG, PCI was performed less frequently, that is, 78.9% versus 93.9%; of those with prior CABG receiving PCI, Thrombolysis In Myocardial Infarction (TIMI) flow grade 3 was also restored less often, that is, 82.5% versus 91.6% (both $p < 0.001$). In prior CABG, there was a nearly even designation of the IRA as a bypass graft ($n = 63$) versus a native vessel ($n = 55$): IRA post-PCI TIMI flow grade 3 was achieved in 66.7% versus 88.0%, respectively ($p = 0.043$). Prior CABG patients had increased 90-day death and composite 90-day death/congestive heart failure/shock. Excess death remained significant after multivariable adjustment (hazard ratio: 1.9, 95% confidence interval: 1.08 to 3.33, $p = 0.025$). When prior CABG patients were stratified by the type of IRA, there was further discrimination of the increased 90-day death, that is, 19% bypass graft ($n = 63$) versus 5.7% native vessel ($n = 55$, $p = 0.05$), respectively.

Conclusions Prior CABG patients with STEMI are less likely to undergo acute reperfusion, have worse angiographic outcomes following primary PCI, and higher 90-day mortality. These findings are especially applicable when the IRA was a bypass graft. (J Am Coll Cardiol Intv 2010;3:343–51)

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Despite increased use of secondary prevention measures, the progression of native coronary atherosclerosis and accelerated atherosclerosis in saphenous vein grafts remains problematic. Attrition in these grafts occurs at a rate of at least 3% to 5% yearly (1–5). Commensurate with these phenomena and the aging population there is an increase in the number of patients with prior coronary artery bypass grafting (CABG) suffering acute ST-segment elevation myocardial infarction (STEMI).

Despite this, limited information exists concerning these patient outcomes following reperfusion therapy, and they are frequently excluded from clinical trials. Available evidence suggests that fibrinolytic therapy may be less effective in this population (6). This may relate in part to their increased age, prevalence of comorbidities, diminished left ventricular function, overall magnitude of atherosclerosis, and the impact of degenerative vein grafts as culprit vessels (7). Although timely expert primary percutaneous coronary intervention (PCI) is the preferred strategy for STEMI patients, current guidelines are conspicuously silent and do not provide specific recommendations on the optimal reperfusion strategy in patients with prior CABG (8,9).

Abbreviations and Acronyms

CABG = coronary artery bypass grafting
CHF = congestive heart failure
ECG = electrocardiogram
IRA = infarct-related artery
PCI = percutaneous coronary intervention
ST-E = ST-segment elevation
STEMI = ST-segment elevation myocardial infarction

Furthermore, data describing the prevalence of bypass graft versus native coronary vessel as the culprit infarct-related artery (IRA) and the likelihood of angiographic success after primary PCI is limited. To address these issues, we examined the outcomes of STEMI patients with a past history of CABG in the APEX-AMI (Assessment of Pexelizumab in Acute Myocardial Infarction) trial (10), a large trial of primary PCI in STEMI patients (10).

Methods

Patients. The entry criteria and main results for the APEX-AMI trial have been described previously (10). Enrollment began on July 13, 2004, and ended on May 11, 2006, which resulted in a final population of 5,745 patients from 296 participating hospitals in 17 countries. Enrollment criteria were ≥18 years old, within 6 h of symptom onset, and "high-risk" electrocardiograms (ECGs) qualified by fulfilling any of the following 3 criteria: 1) 2 mm of ST-segment elevation in 2 anterior or lateral leads; 2) 2 mm of ST-segment elevation in 2 inferior leads coupled with ST-segment depression in 2 contiguous anterior leads for a total ST-segment deviation of 8 mm; or 3) new left bundle-branch block with at least 1 mm of concordant ST-segment elevation. They were expected to undergo primary PCI, and there was no exclusion for prior CABG. No treatment difference attributable to pexelizumab was observed; therefore, for the current analysis, randomized treatment groups were combined.

End points. Prospectively identified end points included 90-day death and the 90-day composite of death, centrally adjudicated congestive heart failure (CHF), or cardiogenic shock. Briefly, CHF included new or worsening CHF that began or persisted 24 h after randomization or rehospitalization for CHF. Cardiogenic shock was defined as hypotension (<90 mm Hg systolic blood pressure) that lasted for at least 1 h, was not responsive to fluid resuscitation and/or heart rate correction, was believed to be secondary to cardiac dysfunction, and was associated with hypoperfusion.

ECG analysis. The electrocardiograms were evaluated centrally at the ECG core laboratories (Canadian VIGOUR Centre, Edmonton, Alberta, Canada, and Duke Clinical Research Institute, Durham, North Carolina) without knowledge of patient characteristics, treatment assignment, procedural results, or clinical outcomes. ST-segment elevation sums (ΣST-E) were calculated as follows: for anterior infarction, the sum of ST-E in V_1 to V_6, I, and aVL; for inferior infarction, the sum of ST-E in leads II, III, aVF, V_5, and V_6. ST-segment deviation sums were calculated by adding the sum of ST-segment depression measured in reciprocal leads to ΣST-E. Leads II, III, and aVF were considered potential reciprocal leads for anterior infarctions, and leads V_1 through V_4 were considered potential reciprocal leads for inferior infarctions. Single-lead ST-E recovery (percent reduction in ST-E from baseline to post-PCI ECG in the lead with maximum baseline ST-E) was analyzed in 2 categories (<50%, ≥50%).

Angiographic analysis. Site investigators completed the angiographic analysis on all enrolled patients blinded to study treatment. This included: determination of the culprit coronary vessel (left main, left anterior descending, circumflex, right coronary artery, or bypass graft), documentation of severity of coronary artery disease (1- vs. 2- vs. 3-vessel disease), and determination of Thrombolysis In Myocardial Infarction (TIMI) flow grade before and after PCI.

Cardiac biomarkers. Biomarkers of myocardial necrosis (i.e., peak samples of creatine kinase [U/l], creatine kinase-myocardial band [μg/l], troponin I [μg/l], or troponin T [μg/l]) were collected and processed according to local protocols. Values were transformed into a ratio by dividing the local patient value (in U/l or μg/l) by upper limit of normal for that laboratory. Combined peak biomarkers' upper limit of normal was constructed by using a hierarchy of taking creatine kinase first, if missing then creatine kinase-myocardial band, if missing then troponin I, or if missing then troponin T.

Statistical analysis. Data were reported as percentages for discrete variables and continuous variables as medians with 25th and 75th percentiles with chi-square tests and non-parametric (Mann-Whitney or Kruskal-Wallis) tests for

Table 1. Selected Baseline Characteristics, In-Hospital Procedures, and Medications According to Prior CABG Status

	No Prior CABG	Prior CABG	p Value
Baseline characteristics			
n	5,617	128	
Age, yrs, median (IQR)	61 (52.0–71.0)	69 (58.3–76.0)	<0.001
Women, n (%)	1,306 (23.3)	18 (14.1)	0.014
Hypertension, n (%)	2,749 (49.0)	90 (70.3)	<0.001
Prior myocardial infarction, n (%)	612 (10.9)	82 (64.1)	<0.001
Prior PCI, n (%)	881 (9.2)	32 (36.7)	<0.001
Prior CHF, n (%)	187 (3.3)	21 (16.4)	<0.001
Diabetes mellitus, n (%)	187 (15.7)	32 (25.0)	0.007
Heart rate, beats/min, median (IQR)	75 (65.0–86.0)	75 (65.0–85.0)	0.405
Systolic BP, mm Hg, median (IQR)	133 (117.0–150.0)	135 (115.0–154.0)	0.586
Killip class >I, n (%)	595 (10.6)	16 (12.5)	0.492
Noninferior myocardial infarction, n (%)	3,287 (59.9)	66 (53.2)	0.139
Symptom onset to randomization (min), median (IQR)	166 (119.0–237.0)	167.5 (120.5–269.3)	0.439
Randomization to PCI (min), median (IQR)	30 (21.0–43.0)	37 (28.0–55.0)	<0.001
In-hospital procedures, %			
Repeat PCI	7.0	4.7	0.317
Cardiac surgery	3.6	3.1	0.790
Mechanical ventilation	3.8	4.7	0.619
Permanent pacemaker	0.8	1.6	0.378
AICD	0.4	3.9	<0.001
IABP	7.7	9.4	0.483
LVAD	0.4	1.6	0.05
Dialysis	0.5	0.8	0.604
Medications, %			
Aspirin			
Prior to randomization	69.6	85.2	0.001
Within 24 h of hospitalization	97.0	96.1	0.750
Discharge	94.5	87.5	0.002
Thienopyridine	25.6	24.2	0.716
Prior to randomization			
In-hospital	92.8	85.9	0.003
Discharge	87.8	76.6	<0.001
Both aspirin and thienopyridine in-hospital	91.3	83.6	0.003
GPI during index hospitalization	69.5	65.6	0.334
GPI prior to cardiac catheterization (among all GPI)	71.8	65.5	0.221
Beta-blocker			
Prior to randomization	34.6	63.3	<0.001
In-hospital	84.8	82.0	0.628
Discharge	83.7	82.8	0.212
Statin	19.0	60.9	
Prior to randomization			<0.001
In-hospital	91.0	91.4	0.946
Discharge	91.3	82.8	0.003
ACE inhibitor	18.6	35.9	<0.001
Prior to randomization			
In-hospital	79.5	71.9	0.095
Discharge	77.3	68.0	0.039

ACE = angiotensin-converting enzyme; AICD = automatic implantable cardioverter-defibrillator; BP = blood pressure; CABG = coronary artery bypass graft; CHF = congestive heart failure; GPI = glycoprotein IIb/IIIa receptor inhibitor; IABP = intra-aortic balloon pump; IQR = interquartile range; LVAD = left ventricular assist device; PCI = percutaneous coronary intervention.

differences among groups. Kaplan-Meier survival estimates were used to compare time to the first occurrence of death or the composite of death, CHF, or shock after randomization according to prior CABG status, with pairwise differences tested using the log-rank test. To account for other baseline confounders of these associations, multivariable models were developed using Cox proportional hazards regression and adjusted hazard ratios and corresponding 95% confidence intervals for prior CABG status are reported. Covariates considered in these models included age, diabetes, systolic blood pressure, heart rate, Killip class, MI location, ΣST-segment deviation on the admission ECG for 90-day death and age, sex, prior MI, diabetes, systolic blood pressure, heart rate, Killip class, ΣST-segment deviation on the admission ECG for 90-day death/CHF/shock.

All hypotheses were determined a priori and as such no adjustments were made for multiple comparisons (i.e., all tests were 2-sided, with a 5% level of significance). All analyses were performed with SAS statistical software (version 9.1.3, SAS Institute, Cary, North Carolina).

Results

A total of 5,745 patients were enrolled in APEX-AMI. Of the total, 128 patients (2.2%) had a prior CABG in which the infarct-related culprit vessel was determined to be a bypass graft in 63 and a native coronary artery in 55 (IRA was not discernible in 10) patients.

In Table 1, baseline characteristics, in-hospital procedures, and medication use of the study population comparing the 128 patients with prior CABG to those without prior CABG are presented. Those with prior CABG were older, more likely to be men, and had more comorbidities including a history of hypertension, MI, PCI, CHF, and diabetes mellitus. The time from randomization to PCI was modestly delayed (median: 7 min) in those with prior CABG. Consistent with the known diagnosis of coronary artery disease, those with prior CABG had a higher use of evidence-based medications at the time of presentation. Despite this, at the time of discharge, evidence-based medical therapies were used less frequently than in those without prior CABG (Table 1). Of patients enrolled in North America, 3.2% had prior CABG, a higher percentage than the 1.8% outside of North America.

Although their overall risk profile was higher, as seen in Table 2, the extent (sum) of baseline ST-segment elevation and deviation was lower in those with prior CABG. There was a trend to achieving less ST-segment elevation resolution in the prior CABG group (<50% resolution, 36.6% vs. 29.1%, p = 0.093). Peak cardiac biomarkers were also lower in the prior CABG patients.

Angiographic characteristics, revascularization procedures, and 90-day clinical outcomes are presented in Table 3. Patients with prior CABG were more likely to have multivessel coronary artery disease and approximately half of this group had a bypass graft identified as their IRA. Prior CABG patients were less likely to undergo reperfusion, that is, primary PCI was undertaken in only 78.9% of those with versus 93.9% (p < 0.001) of those without prior CABG. Urgent CABG within 24 h was infrequent and similar between the 2 groups. Overall, 18.8% of those with prior CABG received no acute reperfusion compared with 5.0% in the comparison group (p < 0.001). There was no difference in pre-PCI culprit artery TIMI flow grade be-

Table 2. ECG Analysis and Peak Cardiac BM According to Prior CABG Status

	No Prior CABG	Prior CABG	p Value
n	5,617	128	
Baseline ΣST-segment elevation, mm, median (IQR)	10.0 (7.0–15.0)	7.5 (5.0–11.0)	<0.001
Baseline ΣST-segment deviation, mm, median (IQR)	13.5 (9.5–19.0)	11.0 (7.5–14.0)	<0.001
Single-lead ST-segment elevation resolution, n (%)			
<50%	1,497 (29.1)	41 (36.6)	0.093
≥50%	3,568 (70.9)	71 (63.4)	
n (peak CK)	4,272	91	
Peak CK ULN, median (IQR)	9.43 (4.44–17.7)	5.38 (2.69–12.5)	<0.001
n (peak CK-MB)	2,193	60	
Peak CK-MB ULN, median (IQR)	28.6 (11.8–53.1)	17.5 (7.12–36.8)	0.004
n (peak TnI)	2,953	72	
Peak TnI ULN, median (IQR)	233.5 (74.3–671.4)	178.8 (36.2–501.8)	0.065
n (peak TnT)	1,437	24	
Peak TnT ULN, median (IQR)	85.5 (30.3–188.3)	50.1 (9.1–78.5)	0.010
n (combined BM)	5,250	114	
Combined peak BM ULN, median (IQR)	11.3 (5.0–23.7)	7.6 (2.9–17.4)	<0.001

BM = biomarkers; CK = creatine kinase; CK-MB = creatine kinase-myocardial band; ECG = electrocardiogram; TnI = troponin I; TnT = troponin T; ULN = upper limit of normal; other abbreviations as in Table 1.

Table 3. Angiographic, Revascularization Characteristics and 90-Day Clinical Outcomes According to Prior CABG Status

	No Prior CABG	Prior CABG	p Value
n	5,617	128	
Primary angiography, n (%)	5,602 (99.8)	127 (99.2)	0.182
Multivessel disease, n (%)	2,252 (40.2)	104 (81.9)	<0.001
Culprit artery, n (%)			<0.001
RCA	1,929 (34.3)	19 (15.2)	
LCx	593 (10.6)	10 (8.0)	
LAD	2,901 (51.6)	23 (18.4)	
Left main	33 (0.6)	3 (2.4)	
Graft	0 (0)	63 (50.4)	
Unknown	28 (0.5)	3 (2.4)	
None	101 (1.8)	4 (3.2)	
Missing n	32	3	
Pre-PCI TIMI flow grade, n (%)			0.677
0/1	4,032 (73.8)	86 (77.5)	
2	770 (14.1)	14 (12.6)	
3	658 (12.1)	11 (9.9)	
Primary PCI, n (%)	5,272 (93.9)	101 (78.9)	<0.001
Use of atherectomy/thrombectomy, n (%)	234 (4.4)	17 (16.8)	<0.001
Urgent (<24 h symptom onset) cardiac surgery (and did not undergo primary PCI), n (%)	60 (1.1)	3 (2.3)	0.165
No urgent revascularization (no urgent cardiac surgery or primary PCI), n (%)	242 (5.0)	24 (18.8)	<0.001
Post-PCI TIMI flow grade, n (%) in those with primary PCI	n = 5,272	n = 101	<0.001
0/1	110 (2.1)	6 (6.2)	
2	328 (6.3)	11 (11.3)	
3	4,800 (91.6)	80 (82.5)	
90-day clinical outcomes, n (%)			
Death	256 (4.6)	15 (11.9)	0.001
CHF	267 (4.8)	8 (6.3)	0.4
Shock	188 (3.3)	8 (6.3)	0.082
Death/CHF/shock	565 (10.1)	21 (16.4)	0.019

LAD = left anterior descending artery; LCx = left circumflex artery; RCA = right coronary artery; TIMI = Thrombolysis In Myocardial Infarction; other abbreviations as in Table 1.

tween those with versus without prior CABG. The use of atherectomy or thrombectomy devices was higher in the prior CABG cohort (16.8% vs. 4.4%, p < 0.001). Those in the prior CABG cohort receiving primary PCI achieved lower post-PCI TIMI flow grade 3 rates: 82.5% as compared to 91.6% in the no prior CABG group (p < 0.001).

Prior CABG patients were more likely to die within 90 days (11.9% vs. 4.9%, p [log-rank] <0.001) (Fig. 1A) or experience death, CHF, or shock (16.4% vs. 10.1%, p [log-rank] = 0.014) (Fig. 1B) compared to those without prior CABG (Table 3). After multivariable adjustment, prior CABG was significantly associated with a 90% relative increase in the hazard of 90-day death (Fig. 2).

Investigators reported more operator-defined technical limitations in prior CABG patients not receiving primary PCI (Table 4). When these patients were compared with their counterparts without prior CABG, who were also not receiving primary PCI, the prior CABG group had increased 90-day clinical events (Table 4). Additionally, despite higher baseline coronary perfusion (TIMI flow grade 3: 29.4% [5 of 17] vs. 6.4% [6 of 94], p = 0.012), prior CABG patients not receiving primary PCI (n = 27) had increased 90-day events compared with prior CABG patients receiving primary PCI (n = 101): 90-day death: 23.1% (6 of 27) versus 9.0% (9 of 101) (p = 0.082), and 90-day death/CHF/shock: 25.9% (7 of 27) versus 13.9% (14 of 101) (p = 0.149), respectively.

Selected baseline and post-randomization characteristics are shown in Table 5 according to whether prior CABG patients had their IRA identified as a bypass graft or native coronary vessel. Despite similar (or better) pre-PCI TIMI flow grade and a higher use of thrombectomy devices; those with a graft IRA had decreased post-PCI TIMI flow grade (Table 6). When the IRA was a bypass graft, 90-day clinical events were increased (Figs. 3A and 3B). After multivariable adjustment, there was no significant excess hazard of 90-day death or composite end point associated in CABG patients with a native vessel IRA compared with patients without prior CABG (Fig. 4). However, in prior CABG patients

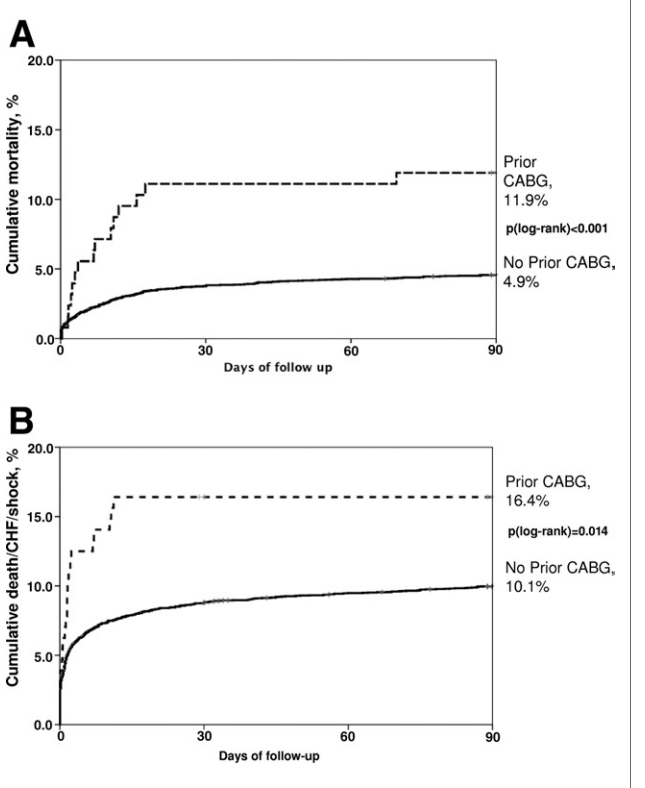

Figure 1. Kaplan-Meier Curves for 90-Day Clinical Outcomes

Kaplan-Meier curves for 90-day death according to prior coronary artery bypass graft (CABG) **(A)** and for 90-day death/congestive heart failure (CHF)/shock according to prior CABG **(B)**.

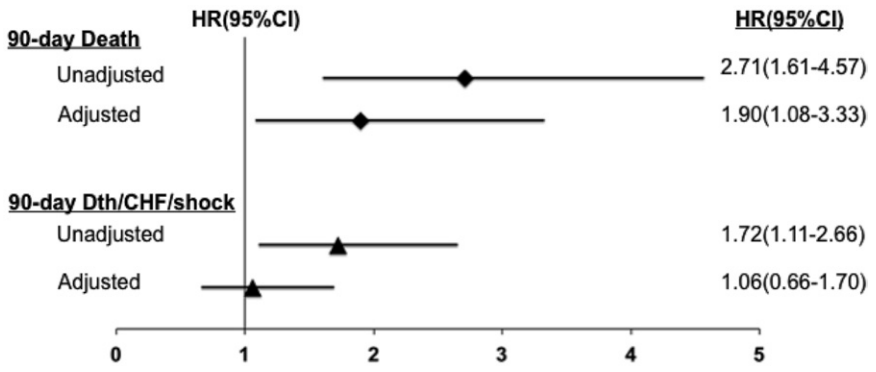

Figure 2. Associations Between Prior CABG and 90-Day Clinical Outcomes

Unadjusted and adjusted associations between prior CABG status and 90-day clinical outcomes. Hazard ratios (HR) (95% confidence intervals [CI]) are presented. Covariates used in the adjustment of 90-day death (♦) included: age, diabetes, systolic blood pressure, heart rate, Killip class, myocardial infarction (MI) location, ΣST-segment deviation on the admission electrocardiogram (ECG); and for 90-day death/CHF/shock (▲): age, sex, prior MI, diabetes, systolic blood pressure, heart rate, Killip class, ΣST-segment deviation on the admission ECG. Abbreviations as in Figure 1.

with a bypass graft IRA, there was a significant 3-fold increase in the hazard of 90-day death (Fig. 4).

Discussion

These data from a large cohort of STEMI patients in APEX-AMI provide new insights into the contemporary prevalence of prior CABG and its relationship to outcomes. First, STEMI patients with prior CABG exhibit a smaller baseline territory at risk as measured by 12-lead ECG and less myocardial necrosis but have more frequent clinical comorbidities and increased 90-day clinical events including mortality. Second, those patients with prior CABG were less likely to receive urgent mechanical reperfusion; in fact, 21% did not receive their planned primary PCI. Those not receiving primary PCI were at particularly increased risk of 90-day clinical events when compared with other prior CABG patients receiving primary PCI as well as that cohort of patients without prior CABG who also did not receive primary PCI. Third, in those prior CABG STEMI patients receiving primary PCI, TIMI flow grade 3 was less frequently achieved and ST-segment resolution was less common. Of particular interest, among the prior CABG group was the nearly equal distribution of the IRA between bypass grafts and native coronary vessels. Although no obvious

Table 4. Investigator-Determined Reason for No Primary PCI, Initial TIMI Flow Grade, and 90-Day Clinical Outcomes According to Prior CABG Status

	No Prior CABG	Prior CABG	p Value
n (no primary PCI)	342	27	
Reasons provided by investigator, n (%)			
No culprit lesion identified	112 (32.7)	9 (33.3)	
Culprit lesion is patent	37 (10.8)	2 (7.4)	
Technical limitations	82 (24.0)	10 (37.0)	
Need for CABG	96 (28.1)	5 (18.5)	
Catheterization not performed	12 (3.5)	1 (3.7)	
Other	3 (0.1)	—	
Pre-PCI TIMI flow grade 3, n (%)	112 (44.4)	5 (29.4)	0.313
90-day death, n (%)	29 (8.5)	6 (23.1)	0.028
90-day death/CHF/shock, n (%)	54 (15.8)	7 (25.9)	0.180

Abbreviations as in Tables 1 and 3.

Table 5. Selected Patient Characteristics According to Graft IRA Versus Native IRA in Prior CABG Patients

	IRA Graft	Native IRA	p Value
n	63	55	
Age, yrs, median (IQR)	69 (60.0–76.0)	67 (56.0–83.4)	0.389
Women, n (%)	6 (9.5)	10 (18.2)	0.189
Hypertension, n (%)	44 (69.8)	36 (65.5)	0.694
Prior MI, n (%)	44 (69.8)	31 (56.4)	0.179
Prior PCI, n (%)	22 (34.9)	20 (36.4)	1.000
Prior CHF, n (%)	13 (20.6)	5 (9.1)	0.123
Diabetes mellitus, n (%)	19 (30.2)	9 (16.4)	0.088
Heart rate, beats/min, median (IQR)	75 (60.0–83.0)	74 (65.0–85.0)	0.779
Systolic BP, mm Hg, median (IQR)	140 (115.0–158.0)	135 (121.0–153.0)	0.869
Killip class >I, n (%)	8 (12.7)	7 (12.7)	1.000
Noninferior MI, n (%)	33 (55.0)	23 (42.6)	0.196
Symptom onset to randomization, min, median (IQR)	173 (125.0–280.0)	156 (116.0–270.0)	0.426
Randomization to PCI, min, median (IQR)	40 (24.5–64.5)	34 (29.0–48.0)	0.472
Both aspirin and thienopyridine in-hospital	85.7%	85.5%	1.000
GPI during index hospitalization	77.8%	58.2%	0.022
GPI prior to cardiac catheterization (among all GPI)	67.3%	62.5%	0.811

IRA = infarct-related artery; MI = myocardial infarction; other abbreviations as in Table 1.

Table 6. Angiographic, ECG Measures, and 90-Day Clinical Outcomes in Prior CABG Patients According to Graft IRA Versus Native IRA

	Graft IRA (n = 63)	Native IRA (n = 55)	p Value
Pre-PCI TIMI flow grade, n (% valid)			0.020
0/1	41 (71.9)	43 (82.7)	
2	12 (21.1)	2 (3.8)	
3	4 (7.0)	7 (13.5)	
Culprit artery, n (% valid)			
RCA	—	19 (34.5)	
LCx	—	10 (18.2)	
LAD	—	23 (41.8)	
LM	—	3 (5.5)	
GLAD-LIMA	1 (1.6)	—	
GLAD-SVG	18 (29.0)	—	
GLCX-SVG	13 (21.0)	—	
GRCA-SVG	30 (48.4)	—	
Unknown	1	—	
Atherectomy/thrombectomy, n/N (%)	13/53 (24.5)	4/47 (8.5)	0.060
Post-PCI TIMI flow grade, n (% valid)			
0/1	6 (12.0)	0 (0.0)	0.040
2	6 (12.0)	4 (8.7)	
3	38 (76.0)	42 (91.3)	
Baseline ΣST-segment elevation, mm, median (IQR)	7.5 (4.6–11.4)	7.0 (5.0–11.0)	0.637
Baseline ΣST-segment deviation, mm, median (IQR)	11.0 (8.0–15.3)	11.3 (7.0–13.6)	0.297
Single-lead ST-segment elevation resolution, n (% valid)			
<50%	22 (40.0)	16 (32.0)	0.423
≥50%	33 (60.0)	34 (68.0)	
n (peak combined BM ULN)	60	45	
Peak combined BM ULN, median (IQR)	10.6 (3.2–17.4)	7.3 (3.7–20.0)	0.912
90-day clinical outcomes, n (%)			
Death	12 (19.0)	3 (5.7)	0.050
Death/CHF/shock	14 (22.2)	7 (12.7)	0.230

GLAD = graft LAD; GLCX = graft LCx; GRCA = graft RCA; LIMA = graft left internal mammary artery; LM = left main artery; SVG = saphenous vein graft; other abbreviations as in Tables 1 to 3 and 5.

differences in patient characteristics were evident between these groups, those with a bypass graft IRA had diminished post-PCI TIMI flow grade (despite increased use of thrombectomy/atherectomy devices) and increased risk of adverse clinical events.

Consistent with prior reports, those STEMI patients with prior CABG were older with an increased burden of comorbidities (6,7,11–14). Despite this, and within the confines of a clinical trial with rigorous ECG entry criteria, this group presented with less baseline ST-segment elevation (ΣST-E) and ST-segment deviation (ΣST-segment deviation) suggesting a smaller myocardial territory at risk. This is well aligned with the finding of less biomarker-evident myocardial necrosis and prior evidence in STEMI patients with prior CABG receiving fibrinolysis (6). The basis for this finding is unclear but could relate to the dual circulation provided through native and bypass grafts and/or increased presence of collateral blood vessels in conjunction with chronic severe coronary artery disease. It is also possible that the index STEMI occurred in a region with prior MI.

It is notable in our study that 21% of prior CABG STEMI patients with planned primary PCI failed to receive reperfusion despite undergoing angiography whereas in those without prior CABG only 6.1% failed to receive primary PCI. The investigators cited the main reason for not proceeding with primary PCI as technical limitations (37%) followed by an inability to identify a culprit vessel (33%). There was no evidence of a protective effect of prior CABG in patients that failed to receive primary PCI; in fact, the 90-day mortality in this group was 3 times greater than those without prior CABG not receiving primary PCI (23.1% vs. 8.5%, p = 0.028). Hence it seems probable that

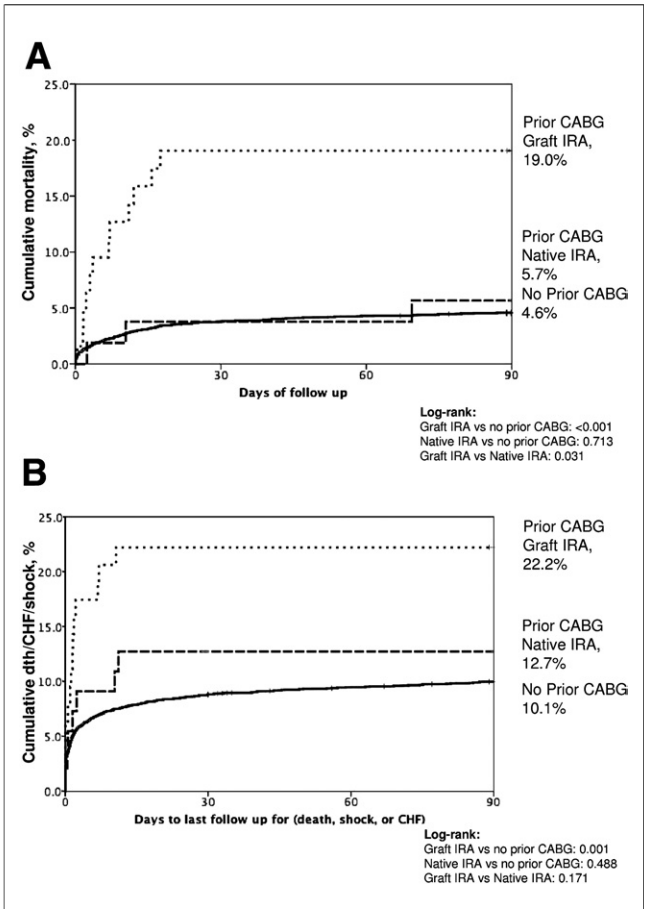

Figure 3. Kaplan-Meier Curves for 90-Day Outcomes for No Prior CABG, Prior CABG with Native IRA, and Prior CABG with Graft IRA Death

Kaplan-Meier curves for 90-day death according to prior CABG—graft versus native infarct-related artery (IRA) **(A)**—and for 90-day death/CHF/shock according to prior CABG—graft IRA versus native IRA **(B)**. Abbreviations as in Figure 1.

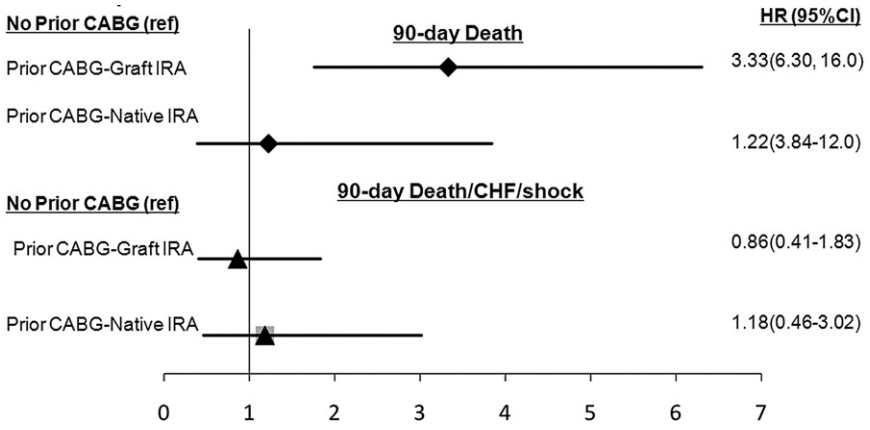

Figure 4. Associations Between Prior CABG Graft Versus Native IRA and 90-Day Clinical Outcomes

Unadjusted and adjusted associations between prior CABG status and native versus graft IRA for 90-day clinical outcomes. Hazard ratios (95% CI) are presented. Covariates used in the adjustment of 90-day death (♦) included: age, diabetes, systolic blood pressure, heart rate, Killip class, MI location, ΣST-segment deviation on the admission ECG; and for 90-day death/CHF/shock (▲): age, sex, prior MI, diabetes, systolic blood pressure, heart rate, Killip class, ΣST-segment deviation on the admission ECG. Abbreviations as in Figures 1 to 3.

this high-risk prior CABG patient cohort with STEMI for whom primary PCI was planned failed to receive reperfusion therapy due to the complexity of the IRA disease. This incidence of no acute reperfusion is of concern, and strategies to optimize reperfusion in this group require further assessment.

Although the efficacy of reperfusion therapy is established in STEMI patients, reperfusion success rates in patients with previous CABG is less well characterized. It has been postulated to be markedly reduced given the large amount of atherosclerotic material and thrombus burden with limited runoff found in occluded saphenous vein grafts. Increased mortality was shown in GUSTO-1 (Global Utilization of Streptokinase and TPA for Occluded Arteries I) trial (1990 to 1993) following reperfusion with tissue-type plasminogen activator where prior CABG patients (n = 1,784) had a 30-day mortality of 10.7% versus 6.7% in those without prior CABG (n = 39,147) ($p < 0.001$) (6). The prior CABG group in GUSTO-1 also had more pulmonary edema, sustained hypotension, or cardiogenic shock and worst angiographic outcomes achieving TIMI flow grade 3 rate of approximately 31% versus 49.2% in those without prior CABG. These results are similar to those in the current analysis from a study performed a decade later where 90-day mortality was 11.9% versus 4.6% for those with or without prior CABG ($p < 0.001$). In NRMI-2 (Second National Registry of Myocardial Infarction) database (n = 45,925), among the prior CABG STEMI patients that received either tissue-type plasminogen activator (n = 2,544) or underwent primary PCI (n = 375), there was no significant difference in the in-hospital clinical outcomes: in-hospital mortality: 7.7% versus 8.0%, and death/nonfatal stroke: 8.6% versus 8.5%, respectively (12). The optimal mode of reperfusion in the population of patients with prior CABG requires further systematic investigation.

Within the current analysis it appears the majority of risk related to prior CABG occurred in those in whom the interventional cardiologist deemed that the IRA was a bypass graft. In fact, there was no difference in outcomes in prior CABG patients with a native vessel IRA than in patients without prior CABG. These results confirm prior registry data obtained from 1991 to 1997, based upon 128 prior CABG patients compared with 944 without prior CABG with the culprit artery being a native vessel (n = 65) and bypass graft (n = 63) (15). After multivariate logistic regression analysis correcting for baseline differences, prior history of CABG was not associated with adverse events but treatment of bypass vein graft remained independently associated with adverse cardiac events (relative risk: 1.48, 95% confidence interval: 1.07 to 2.03; $p = 0.02$). This is also supported by a secondary analysis from PAMI-2 (Second Primary Angioplasty in Myocardial Infarction Trial) study, which compared primary PCI bypass graft (n = 32) to all patients with native coronary artery primary PCI (n = 1,068); where in-hospital mortality was 9.4% versus 2.6%, respectively ($p = 0.02$) (13). Mechanisms to minimize adverse clinical events in patients with prior CABG and bypass culprit IRA should be a priority of future research.

Study limitations. Within APEX-AMI, which had strict 12-lead ECG enrollment criteria, 2.2% of randomized patients had prior CABG, which represented a selected population. Multivariate adjustments may not be equally appropriate to both groups due to the difference in sample size between those with or without prior CABG. Although the current analysis is based upon a large trial, it remains

limited by the modest sample size. This is especially relevant to the analysis of the IRA in the prior CABG group, which should be interpreted with caution.

Conclusions

Prior CABG patients with STEMI are less likely to undergo acute reperfusion, have worse angiographic outcomes following primary PCI, and have higher 90-day death. These findings are especially applicable when the IRA was a bypass graft. Further investigation into the management of this high-risk patient population is warranted and consensus clinical guidelines should address their treatment.

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Key Words: coronary artery bypass graft ■ percutaneous coronary intervention ■ ST-segment elevation myocardial infarction.